## I – Problem Statement Title (04-EQ003)

**Determine the Seismic and Service Load Response of "Skewed" Post-Tensioned, Concrete Box-Girder Bridges To Improve Safety and Reduce Impacts To Traffic**

## II - Research Problem Statement

**Question: How do designers efficiently estimate the response of "skewed" post-tensioned concrete box girder bridges to predict the seismic capacity and service load performance in order to improve safety and reduce impacts to traffic?**

Bridge engineers commonly use two dimensional analyses to determine the capacity of bents, frames, and bridges. However, this simple approach may be inadequate to capture the three-dimensional behavior of skewed, post-tensioned, concrete box-girder bridges. Research is needed to ensure that our accuracy in determining the capacity of this type of bridge is sufficient. Concerns include the following aspects of skewed bridges:

- Skewed bridge rotation and unsymmetrical shear key effect
- Modeling of soil spring at skewed abutments
- Moment sharing of girders and effective width of superstructure in skewed bridges
- Effect of skew angle in response of the bridge
- Limitations of 2-D elastic or push analysis in skewed bridges
- The column-cap joint shear reinforcement in skewed bridges
- Seat width requirements at abutments and hinges
- Modeling of pier wall in skewed bridges
- Verification of analytical models (using tools similar to those used at Caltrans) in an early phase that might be followed by experimental studies in future phases

## III - Objective

Provide guidelines on performing pushover and other types of analysis of skewed bridges, and a straightforward procedure for bridge designers to perform analysis that captures the behavior of skewed bridges, using software similar to those used at Caltrans.

## IV - Background

Skewed post-tensioned, concrete box-girder bridges have suffered severe damage and collapse in past earthquakes. When excited, skewed bridges tend to rotate more than the non-skewed bridges with greater vulnerability. Bridge design engineers require more efficient analytical tools to predict the seismic capacity and service load performance of skewed bridges.

## V – Statement of Urgency and Benefits

### A. Support of Department's Mission/Goals:

**(Improving Mobility: Safety and Performance)** Proper design and detailing of skewed bridges would enhance the performance during an earthquake, particularly the Department's "no collapse" criteria. The performance of Gavin Canyon Bridge in the 1994 Northridge earthquake is a good case example of the effects of skew on the seismic performance of bridges. This important bridge on Interstate I5 collapsed due to large rotational movements that are not captured using standard analysis techniques. There was a large skew on this bridge and it is suspected that this bridge translated and rotated at the same time to become unseated. Study of skewed bridges and prevention of these unusual responses is a major challenge to ensure the safety of bridges in California.

**B. Return on Investment:**

The speed at which bridges can be returned to service after an earthquake is one of the parameters affecting the economy of the area. Better designed and detailed skewed bridges would sustain less damage, and therefore reduce traffic impacts following an earthquake.

## VI - Related Research

Related research includes, but it is not limited to the following items:

1. Mark Eberhard - Seismic Response of Skew Bridges - University of Washington.
2. David Billington - Analysis of Seismic Failure in Skew RC Bridge, Princeton University.
3. A.C. Scordelis et al - Structural Behavior of a Skew Two Span Reinforced Concrete Box Girder Bridge Model - University of California, Berkeley
4. C.D. Comartin and A.C. Scordelis - Analysis and Design of Skew Box Girder Bridges – University of California, Berkeley

## VII - Deployment Potential

1. Review literature for previous and ongoing research on skewed bridges.
2. Develop two and three dimensional skewed bridge computer models and study their behavior.
3. Develop "designer friendly" models and procedures that can capture the essential behavior.